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Economic Impacts of 40 CFR 191:

Environmental Standards and Federal Radiation Protection Guidance for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes

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Environmental Standards and Federal Radiation Protection Guidance for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes

Andrew J. Leiter

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U.S. Environmental Protection Agency
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FOREWORD

This report is a supporting document to the Environmental Protection Agency's Draft Environmental Impact Statement, Environmental Standards and Federal Radiation Protection Guidance for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Wastes, (to be published). The report assumes that the reader already has an understanding of the coverage and rationale for these proposed standards and guides. Therefore, very little background information on the development of the standards has been presented in this report. For more information about the standards, the reader should refer to the Draft Environmental Impact Statement.

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1. EXECUTIVE SUMMARY

The Environmental Protection Agency, Office of Radiation Programs, is developing environmental standards and Federal guidance providing radiation protection from activities pertaining to the management and disposal of spent nuclear fuel, high-level radioactive waste, and transuranic waste. The standards and guides emerging from this development process are collectively referred to in this document as the "high-level waste standard." There are three major parts of this program -- an operations standard, a disposal standard, and radiation protection guidance for disposal. The operations standard imposes limits on exposures from any activity, operation, or process (except for transportation) conducted to prepare spent fuel, high-level or transuranic wastes for storage or disposal, the storage of any of these materials, or activities associated with the disposal of these materials. The disposal standard stipulates performance requirements for the design of a disposal system which would permanently isolate the radioactive wastes. The radiation protection guidance provides general criteria which all Federal agencies should follow in developing their disposal programs.

Several unusual circumstances concerning the high-level waste standard preclude the use of a conventional type of analysis in estimating the economic impact of the standard. The major problem is that the industrial processes covered by these standards are not in operation today and are not scheduled to take place until the latter part of the 1980's, at the earliest. Much of the technology required by these processes has not been

fully defined nor is there much technical experience to draw upon. Since firm plans for the management and disposal of these wastes have not been established, there is much uncertainty as to what would occur in the absence of these standards. Another problem is that the standards focus on providing an adequate level of environmental protection irrespective of specific technology requirements. Therefore, the use of any technology is possible under the standards, provided that the conditions of the standards are met. The comprehensive risk assessment performed in support of the standards does not establish any relationship between alternative risk levels and technology requirements. Since this relationship has not been derived, the costs of alternative risk levels required by the standards cannot be determined. Consequently, an economic impact analysis of regulatory alternatives covering different levels of environmental protection cannot be performed.

Despite the high degree of uncertainty which is inherently characteristic of an analysis of high-level waste management, a quantitative economic analysis, based on available cost estimates and several judgmental assumptions, has been developed. This analysis identifies a range of potential effects which are used to assess the overall economic impact of the EPA standards. It is felt that an economic analysis that is more rigorous than this study cannot be justified in light of the uncertainties involved.

The economic impacts of the high-level waste standard have been evaluated by assuming that some form of waste management and disposal would

take place in the absence of the standard. Consequently, the impact analysis involves estimating the incremental effect of the standard on a reference waste management program. The reference program which was assumed is based on disposal of the waste in a geologic respository. Individual components of the program have been specified and estimates of their likely costs have been derived.

Components of waste management and disposal which might be significantly affected by these standards have been identified, and the expected increases in the cost of these components due to the implementation of the standards have been estimated. The range in the numerical estimates of the economic impacts reflects uncertainty about the size of each impact, but does not reflect the uncertainty associated with the occurrence of this impact. If any of the assumed effects of the standards do not materialize, the expected economic impact should fall below these estimates, possibly even reaching zero.

Commercial and military high-level waste programs are considered separately in the analysis. The costs of transuranic waste management have also been addressed, but the impact of the standards on this waste category could not be determined due to insufficient information.

Three components of the commercial waste management process may be affected by the standards: research and development, encapsulation, and disposal. Research and development costs may increase because of additional site evaluation and more research for improved control technologies

than would otherwise have been conducted. Overall research and development costs account for about six percent of total waste management and disposal costs and are estimated to increase by about 50 to 100 percent as a result of the standards. Encapsulation costs may be affected by the standards to the extent that the standards might require more protective canisters. This cost also represents about six percent of total waste management and disposal costs and is estimated to increase by 40 to 130 percent due to the standards. Disposal costs, which include constructing, operating and backfilling a geologic repository, may be affected since the standards may require the repository to be constructed in an alternative geologic medium which may be more expensive to mine than the medium (salt) assumed in the reference program. Disposal costs represent 21 percent of total waste management costs and are estimated to increase by 30 to 100 percent as a result of the standards.

Based on these estimates of the possible impacts and their relative shares of total waste management and disposal costs, the overall impact of the standards is expected to result in an increase in the total costs of commercial waste management and disposal of about 10 to 35 percent. This estimated increase in total costs is expected to increase the reference waste management charge -- the unit cost that electric utilities (and their customers) will pay for waste management services provided by the Federal Government -- by 15 to 50 percent. The economic consequences of this increase in the waste management charge have been evaluated under a variety of economic assumptions, including a range of values for the reference waste management charge and a range in the share of electric

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energy production derived from nuclear power. Table 1, Part A presents a summary of the impact of the standards on the national average residential electricity rate in 1990. The maximum impact of the standards is estimated to be a less than one percent increase in the national average rate. The conditions for this maximum impact are: a reference waste management charge of 1.4 mills per kwh; a 33 percent nuclear share of electricity generation in 1990; zero growth in the real price of electricity from the base year of 1977 to 1990; and a 50 percent increase in the reference waste management charge due to the standards.

The annual cost of commercial waste management is assumed to equal the projected revenues to be collected from the waste management charge levied on electricity customers. Therefore, the annual cost of the EPA standards in 1990 is estimated by multiplying the increase in the reference waste management charge due to the standards by the nuclear-powered kilowatt-hours of electricity projected for 1990. For this estimation, a single forecast of 1990 nuclear electricity production -- 825 billion kwh -- and ranges of values for the reference waste management charge and the incremental effect of the standards were assumed. This annual cost collected from electricity customers pertains only to the waste resulting from nuclear-powered electricity generated in 1990 and involves waste management activities which will take place some years after 1990. The cost does not cover the waste management activities for commercial waste which exists today nor that which is expected to accumulate between now and 1990. As shown in Part B of Table 1, the annual cost of the standards in 1990 ranges from about $75 to $600 million (expressed in 1978 dollars). Total

TABLE 1

Summary of Economic Impacts of
EPA High-Level Waste Standards

A. Impact on National Average Residential Electricity Rate, 1990

Impact of Standard on Waste Management Charge	Reference Waste Management Charge (.6 mills/kwh)		(1.4 mills/kwh)	
	Realistic Case	Maximum Impact Case	Realistic Case	Maximum Impact Case
15% increase	.1%	.1%	.1%	.2%
50% increase	.2%	.3%	.4%	.7%

B. Annual Cost of EPA Standards, Commercial Waste Management, 1990
(millions of 1978 dollars)

Impact of Standard on Waste Management Charge	Reference Waste Management Charge (.6 mills/kwh)	(1.4 mills/kwh)
15% increase	$ 74	$173
50% increase	$248	$578

C. Impact on Total Cost of Military High-Level Waste Management

Individual Cost Component	Low Impact (millions of 1978 dollars	High Impact undiscounted)
Processing	220	220
Transportation	322	322
Disposal	0	137
Research & Development	156	311
Canisters	160	697
Impact on Total Cost	858	1687
Total Cost, Reference Program	3692	3692
% Increase in Total Cost of Reference Program	23%	46%

electric utility revenues in 1990 are projected to be about 130 billion dollars (also expressed in 1978 dollars). Consequently, although the potential impact of the standards, in absolute terms, appears large, it is small relative to the total cost of electricity production.

Five potential impacts of the standards on the cost of military high-level waste management and disposal have been identified. First, the standards may influence the cost of processing high-level waste by requiring the separation of long-lived technetium-99 for disposal. Second, the standards may affect the canister cost by requiring a more protective canister. Third, transportation costs may be significantly affected by the standards if the standards eliminate the alternative of onsite disposal and require wastes to be disposed in an offsite repository. Fourth, the disposal cost may be affected by the standards if the selected geologic media are more expensive to mine than the media assumed in the base case. Fifth, research and development costs may be increased by requiring more extensive site evaluation to take place and more research for improved control technologies.

Estimates of the possible size of each of these impacts have been developed and then summed to determine the overall effect of the standards on the total cost of military waste management. These impacts are expressed on a total project cost basis in 1978 dollars and pertain to expenditures to be incurred over a period of years in the future which has not yet been determined. Table 1, Part C shows the estimated incremental cost for each component affected by the standards. Processing costs could

increase by 220 million dollars. Additional cost of canisters due to the standards may range from 160 to 697 million dollars. Additional transportation costs are estimated to be 322 million dollars. Disposal costs may increase from zero to 137 million dollars. Research and development costs could increase by 156 to 311 million dollars.

By combining all the estimates of the individual effects, the overall impact of the standards on the total cost of military high-level waste management is expected to range from .9 to 1.7 billion dollars. Compared to a reference onsite geologic disposal program estimated to cost 3.7 billion dollars, the standards' impact may result in a cost increase of 23 to 46 percent.

As stated above, these estimated impacts assume that each of the potential effects of the standards on waste management costs occurs. To the extent that some of the effects do not take place, the economic impact of the proposed standards will be lessened, possibly even reaching zero. In the case of commercial waste, if compliance with the standards can be met by a repository constructed in salt, carbon steel canisters and no additional expenditures for site evaluation and research on improved control technologies, then the impact of the standards will be zero. Likewise, if the conditions of the reference military high-level waste program comply with the standards, then the standards' impact on the cost of military waste management will also be zero.

Since so much uncertainty exists concerning future waste management activities, the selection of a reference program for this study is highly speculative. If reference programs different from the ones used in this analysis are assumed, the economic impacts of the standards will naturally be different. However, since we have used relatively wide ranges of values for (a) the cost of the reference commercial waste program, (b) several economic and energy parameters, and (c) the size of the incremental effect of the standards, we believe that the results of this analysis provide reasonable bounds on the impacts regardless of the speculative nature of projecting future waste management activities.

2. INTRODUCTION

Economic impacts of regulatory policies are generally determined by first deriving a baseline situation which presupposes the absence of the regulation under investigation and, then, by estimating what developments will take place in a situation which is subject to the regulation. The difference in the relevant economic parameters between these two cases is considered to be the economic impact of the policy. The reliability of the estimated economic impact thus becomes a function of the ability to forecast the circumstances of these two situations. The economic impact of EPA's high-level waste standard cannot be estimated in a very rigorous manner since many uncertainties exist concerning waste management activities in the future.[1] With the aid of several judgmental assumptions, however, a range of likely occurrences can be estimated which are used to evaluate the potential economic impact of the standard.

A critical assumption of the analysis is that some form of waste management will take place regardless of the EPA standard. Therefore, the impact analysis involves estimating the incremental effect of the standard on the waste management program that would occur in its absence. This assumption appears reasonable since the issue of waste management has been gaining increasing attention in the political sphere, as illustrated by

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[1]This paper treats the operations standard and the disposal standard as a single entity, unless stated otherwise. The reader should refer to EPA 80 for background information on the development of each of the standards.

several recent developments. These developments include the President's spent fuel policy announcement of October 18, 1977 and the subsequent planning efforts of the Department of Energy (DOE),1 the formation and reports of the Interagency Review Group on Nuclear Waste Management (IRG 79), radioactive waste legislation passed by several states (e.g., California's moratorium on nuclear power expansion, pending a viable waste management program)2, and the President's policy statement to Congress of February 12, 1980 on radioactive waste management (CA 80).

The uncertainty involved in the estimation of the economic impact of the standard stems from two sources: the inability to specify the form of a "baseline" waste management program accompanied by reasonably accurate cost information, and the generic nature of the standard with regard to waste management technology. The primary reason for the first uncertainty is that the processes involved pertain to a future program which is still in the planning stages. Much of the required technology has not been fully defined, nor is there much applicable technical experience from which to make cost determinations. Besides technological considerations, the costs of waste management can significantly be affected by political, administrative, and economic factors. Many studies on waste management costs contain contingencies of some sort to take into account unexpected problems. In fact, one report, in its cost presentation, presumes that

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[1]See (DOE 78a) for background on spent fuel policy.

[2]See testimony of Emilio E. Varanini, Commissioner, California Energy Resources Conservation and Development Commission, in (HRP 77), p.149, for background on the California legislation.

even after disposal operations have begun and waste is placed in a repository, a significant portion of the material will have to be retrieved due to some technical difficulty and re-disposed of in another manner (MHB 78).

Regarding the latter source of uncertainty, the standard does not stipulate how waste should be managed (i.e., a specific disposal technology), but rather it focuses on providing an adequate level of environmental protection from waste management activities. The use of any technology is possible under the standard, provided that the conditions specified in the standard will be met. Since the standard does not require specific technologies, and since the risk limiting capabilities of most of the technologies under consideration are not yet thoroughly described, the impact of the standard becomes hypothetical.

It is the conclusion of EPA, though, that waste disposal in a geologic repository is the technology that is not only the most readily available, but is also the method for which risk assessment methods are most advanced (see EPA 80). Consequently, the economic impact analysis has been derived within the framework of geologic disposal as the reference technology from which to estimate the incremental effect of the standard.

Economic impacts are presented for two categories of high-level waste: spent fuel from commercial reactors and waste products from military weapons programs. The analysis for the former has been undertaken in greater depth than that of the latter for a number of reasons. The groups

affected by the commercial waste program -- that is, the producers and consumers of nuclear power -- can be identified, and thus provide the framework for a detailed economic impact analysis. Identifying individual segments of the general population affected by national defense expenditures is virtually impossible due to the "public good" nature of national defense. In the case of a public good, all members of the population benefit from its use, so that payment of the cost of production from general tax revenues is an acceptable means of financing production. Also, since most of the commercial waste to be disposed of has not yet been generated, the benefits and costs of the activity which produces the waste (nuclear power) must be factored into the decision-making analysis about the type of waste management desired. In other words, the future size of nuclear power industry will have a direct effect on the type of waste management operations which are required. This consideration is much less important for military waste management since substantial amounts of defense waste already exist and which require some form of "management" regardless of the course of future defense activities. Furthermore, analyzing the economic effects of waste management on the future growth of the activity generating the waste is more relevant to commercial nuclear power than to military weapons programs due to the lack of feasible alternatives in the case of national defense. Another reason for the greater attention given to commercial waste management is that the financial planning process is at a more advanced stage than that for military waste, so that more information on the cost of commercial waste management and the methods of financing the program is available.

3. COMMERCIAL WASTE MANAGEMENT

3.1 Overview

Economic impacts resulting from the EPA standard can arise in two basic ways regarding the commercial waste management program.[1] First, the standard may have an effect on the cost of waste management. Since waste is a by-product of the generation of nuclear power, the standard can alter the cost of nuclear power and thus the cost of the production of electricity. Consequently, an impact on electricity rates is created which in turn affects the consumers of electricity. The second type of economic impact that the standard may have, also has an effect on electricity rates, but in a less direct manner. This impact pertains to the effect of the standard on the status of nuclear power as a socially and economically viable energy source. A wide range of possible economic impacts could be estimated depending upon one's scenario of the relationship between the standard and the size of the nuclear power industry. In the extreme case, an environmentally acceptable standard could be devised which could not be met by existing or prospective waste management technology, thereby causing ongoing waste management plans to be scrapped. A likely consequence of this occurrence would be the decline of the nuclear power industry, a situation whose economic impact would be

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[1] "Waste management" includes the handling and storage/disposal of both spent fuel discharged from commercial reactors and high-level waste generated from reprocessing. Under the general context of the term "waste," no distinction between the two types of material is necessary. When used in a specific sense, such as in the discussion of cost considerations, differentiation between the two has been noted.

far-reaching and significant in size. On the other hand, if the standard is one for which compliance is clearly achievable, then the standard might have a positive impact on the growth of nuclear power, perhaps due to the elimination of environmental and political opposition. The result of this situation would not be certain, but if nuclear power is employed in areas where it has a cost advantage over alternative energy sources, then the impact of the standard may be a decrease (or smaller increase) in electricity rates.

This chapter structures the estimation of the economic impacts of the EPA standard according to these two impacts -- the impact on waste management costs and the impact on commercial nuclear power growth. Emphasis has been placed on the former impact since little or no impact is expected in the latter case. This stems from the likelihood that the proposed standard can be met by disposal in a geologic repository, and that the cost of the reference waste management program and the incremental cost of compliance with the standard are not significant enough to alter the relative costs of alternative power plants (i.e., coal versus nuclear). Section 3.2 examines the impact that the standard will have on waste management costs while Section 3.3 discusses the relationship between the standard and commercial nuclear power growth.

3.2 Impact of Standard on Waste Management Costs

As discussed in Chapter 2, the economic impact of the EPA standard was assessed in terms of its incremental effect on the reference waste management program which is assumed to occur in the future without the

standard. The economic impacts of this reference program have been evaluated in terms of price effects on residential electricity customers, on both a nationwide and regional basis, and increases in customers' electric bills. The estimation procedure assumes that the percentage increase in electricity rates due to waste management costs is the same for all types of electricity users. Therefore, the direct price effects on commercial and industrial customers are equal, on a relative basis, to those estimated for residential users. The total annual cost of the waste management program, as reflected by the projected revenues to be collected from a waste management charge, was also estimated. By utilizing the estimated effect of the standard on total waste management costs, the economic impact of the standard was expressed in the same terms as the impacts of the reference program.

Since the estimation of the economic impact of the standard is highly speculative, ranges of values for key parameters were assumed in order to bound the potential impact. Ranges for the cost of the reference program, several economic and energy variables, and the size of the incremental effect of the standard were used to produce these estimates. The reader should, therefore, interpret the results of this analysis as providing estimates of the bounds of the economic impacts rather than an estimate of the most likely economic impacts of the standard.

3.2.1 Economic Impacts of the Reference Waste Management Program

The reference commercial waste management program is based on the geologic disposal of spent fuel. The spent fuel waste form was chosen

instead of high-level waste in light of the deferral on reprocessing and the President's spent fuel policy (see DOE 78a). As a result of this policy, most of the recent analyses of waste management costs use spent fuel as the reference waste material for cost derivations. For the purposes of this study, the cost components were chosen to be: the storage of spent fuel after discharge from the reactor (covering both reactor-site and away-from-reactor (AFR) storage); transportation of the spent fuel from the storage site to a facility designed for encapsulation of the waste; the encapsulation of the waste, which includes the necessary handling and processing before disposal (and which is assumed to be carried out at the disposal site); disposal in a geologic repository (designed with the capability for retrieving the spent fuel); Government research and development costs; Government overhead; and costs for decommissioning (of waste management facilities) and post-operational activities. Substituting processed waste instead of spent fuel would not significantly alter the total unit cost of waste management since the majority of the costs are common to both fuel cycles. Also, in the case of reprocessing, the added cost of solidification of high-level liquid waste would be somewhat offset by the reduced unit cost of disposal relative to the "once through" cycle (ADL 77).

As part of the President's spent fuel policy, it is assumed that utilities will be charged a one-time payment for waste management services provided by the Government. The impact of the commercial waste management program can be estimated by determining the cost to customers of nuclear-powered electricity resulting from the incurrence of this waste management

charge by utilities. Waste management costs expressed on the basis of dollars per kilogram of heavy metal[1] can be converted to an electricity rate basis (mills/kilowatt-hour) by a single factor.[2] The methodology for estimating the economic impacts of increased electric rates from waste management activities is explained in detail in Appendix A.

Estimates of the unit charge for waste management activities are available from several sources, but the ones deemed most appropriate for this analysis were the estimates presented in DOE's preliminary spent fuel charge report (DOE 78b). As of this writing, these estimates are the costs to utilities that are most likely to occur assuming implementation of the spent fuel policy. Although these unit charges are not completely applicable to estimating the total charges to utilities resulting from waste management, since the costs included are only those for services provided by the Government, the estimates nevertheless provide a realistic

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[1]Assumed to be the same as the quantity of uranium contained in the fuel elements before reactor loading (DOE 78b, p.21).

[2]DOE, in their preliminary spent fuel charge report (DOE 78b, p.23) assumes a conversion factor of \$250/kg = 1 Mill/kwh, based on an average thermal efficiency of 34 percent and an average burnup level of 31,000MWD$_{th}$/MTU. This conversion produces the direct fuel cycle cost to electricity customers from utility expenditures for waste management. Indirect charges, which are the carrying charges for recovering the cost of capital between the time revenues are collected by utilities and the time expenditures are paid by the utilities, must also be examined. By assuming that utilities pay for waste management services at the time the electricity is produced (i.e., when revenues are collected), the indirect charges become zero. If payment of expenditures takes place at the time of the planned transfer of waste to the Government (i.e., some years after revenue collection), then the indirect charge is negative, and the total fuel cycle cost to ratepayers is diminished. See DOE 80b for more information on total fuel cycle cost implications.

range from which to begin estimating economic impacts. The sensitivity analysis of the DOE report indicates charges ranging from $112 to $319 per kilogram (DOE 78b, Table 7).1 Adding $33/kg to each of these costs to represent the cost of transportation of spent fuel to Government facilities and converting to mills/kwh results in a range of direct fuel cycle costs of .6-1.4 mills per kwh. We assume that utilities will pay for waste management services at the same time that revenues are collected from electricity customers so that the indirect fuel cycle cost is zero. This assumption creates a "maximum impact" bias in the estimated charge because if instead utilities make payment for waste management services at the time the material is transferred to the Government -- the assumption used in the DOE report -- a negative indirect fuel cycle cost results which reduces the total charge to electricity customers. Technically speaking, using both the estimates from the DOE report to represent the direct charge and assuming utility payment at time of revenue collection is inappropriate without an adjustment to the direct charge for payment at a time "earlier" than that assumed in the DOE report. Earlier payments to the Government for waste management services have the effect of not only increasing the indirect charge but also decreasing the direct charge (see DOE 80b for a discussion of the effect of time of payment on the fuel cycle cost). Therefore, the direct charge, as used in this paper, is overstated. However, since a wide range in this charge has been assumed for estimating economic impacts, the effect of this overstatement becomes insignificant.

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[1]All dollar amounts in this report are expressed on the basis of constant 1978 dollars, unless specified otherwise.

Since the activities under analysis pertain to a future technological process rather than an existing program, the economic impacts stemming from a charge of .6-1.4 mills/kwh have been estimated for a future date at which time, presumably, the waste management program will have been established. The year 1990 has been selected as the date in which to calculate the impact of the program. Two scenarios of energy/economic assumptions were devised for estimating these impacts: a "maximum impact" case and a "realistic" case. The former case represents assumptions that would maximize the economic impact of the waste management program while the latter scenario contains assumptions that are typically categorized as "most likely" or "middle-of-the-road." The direct impact on residential electricity customers was estimated on a national average basis for the high and low waste management charge (.6-1.4 mills/kwh) and the two energy/economic scenarios. The results are displayed in Table 2.

The relative impact on the 1990 U.S. average residential electricity rate from the institution of a waste management charge ranges from an increase of .4 to 1.4 percent. The absolute increase in the average monthly residential electric bill ranges from a minimum of $.10 to a maximum of $.74. The corresponding percentage increases in the electric bill were .3 to 1.4 percent. The minimum percentage increase in the monthly residential electric bill is smaller than the minimum percentage increase in the electricity rate because of the assumption in the "realistic" energy/economic scenario of a nonzero (but inelastic) price elasticity of demand for electricity (see Appendix A for more details).

TABLE 2

National Average Impacts of Reference Commercial Waste Management Program, 1990

Charge for Waste Management (mills/kwh)	Relative Increase in Residential Electricity Rate, 1990		Increase in Monthly Residential Electric Bill, 1990			
	Maximum Impact Case	Realistic Impact Case	Maximum Impact		Realistic Impact	
			Absolute Increase	Relative Increase	Absolute Increase	Relative Increase
.6	.6%	.4%	$.32	.6%	$.10	.3%
1.4	1.4%	.8%	$.74	1.4%	$.24	.7%

NOTE: Monetary figures are expressed in constant 1978 dollars.

A regional analysis of the direct impact of the reference waste management program was also performed to see to what degree individual areas of the country will be affected more than others. Regional variation should account for an upward deviation in the average residential electricity rate of no more than 60 percent of the national impact (expressed on a relative basis). The Boston and Seattle regions are expected to experience the greatest relative impact while the Denver region represents the area with the smallest impact. Variation in regional impacts, on a percentage basis, expected from waste management charges is diminished because the areas with the highest shares of forecasted nuclear power generation -- the New England and Middle Atlantic States -- also are the regions with the highest electricity charge to customers.[1] The higher the price of electricity, the smaller the relative impact of the waste management program. On an absolute basis, regional variation is estimated to result in a maximum upward deviation from the national average impact of about 100 percent, since the impact for the Boston region is about twice the size of the impact for the total United States.

Secondary impacts resulting from the waste management charge -- that is, higher prices for goods and services produced in the commercial and industrial sectors -- have not been explicitly estimated but a brief investigation of their expected magnitude indicates that the impact will be insignificant (see Appendix A).

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[1]It should not be concluded that the reason for these areas exhibiting high electricity prices is the relatively large nuclear share; the high prices are attributed to other factors.

The total annual cost of the reference waste management program in 1990, as reflected by the projected revenues to be collected from a waste management charge of .6 to 1.4 mills/kwh levied on consumers of nuclear powered electricity in that year, ranges from about .5 to 1.2 billion dollars (see Appendix A for the basis of this forecast). This cost does not include the necessary expenditure for reactor-site storage of spent fuel which is assumed to already have been passed on to ratepayers. Though the total dollar amounts reflected in commercial waste management activities may be substantial, the economic disruption resulting from these costs is small because the total costs of electricity generation are so much larger. Total electric utility revenues for the year 1990 are projected to be about $130 billion according to the assumptions of Appendix A. Therefore, the estimated total cost for waste management in 1990 -- .5 to 1.2 billion dollars -- represents .4 to .9 percent of total revenues.

This annual cost collected from electricity customers pertains only to the waste resulting from nuclear-powered electricity generated in 1990 and involves waste management activities which will take place some years after 1990. The cost does not cover the waste management activities for commercial waste which exists today nor that which is expected to accumulate between now and 1990. The cost for the management of future waste is expected to be passed on to electric utility customers according to the principle of public utility regulation that current revenues should be related to all the costs associated with the current generation of electricity. In other words, the people who receive the benefits of electric power should pay, to the degree possible, for all of the costs of

that power, regardless of when these costs take place. Therefore, the cost of managing the waste from each year's nuclear-powered electricity generation should be included in that year's revenues, as this analysis has assumed for 1990. It is uncertain how and by whom (i.e., future ratepayers or stockholders) the cost for commercial waste which exists today, and which has not been paid for by those who have received the benefit of the electricity consumption, will be incurred. This will depend on the actions of the individual State public utility commissions.

In Appendix B, we estimated the total waste management cost for existing spent fuel and the fuel to be used in the future generation of nuclear-powered electricity from 1980 through 1995. The total cost for existing fuel is estimated to range from .9 to 1.5 billion dollars while the waste management cost for the future spent fuel ranges from 6.7 to 15.7 billion dollars. The combined total cost for existing and future waste is, therefore, 7.6 to 17.2 billion dollars. The waste management cost for existing spent fuel represents about 10 percent of the combined total cost (see Appendix B for the basis of these estimates).

3.2.2 Incremental Impacts of the Standard

The impact of the standard on the cost of the reference commercial waste management program was estimated using the following procedure. First, unit costs were developed for each of the individual components of the waste management process to determine their relative importance. Estimating the relative importance of the individual cost components is a

key determinant in assessing the economic impact of the standard, since it enables one to see what portion of the total cost of waste management and disposal may be influenced by the standard. Second, the potential impacts of the standard were identified and the affected cost components were determined. Third, the size of each of the impacts was estimated. Fourth, combining the estimates of the individual impacts with their relative importance factors, produced an estimate of the overall effect of the standard on total waste management costs.

Costs for waste management components are displayed in Table 3. These costs are not engineering costs in the sense that they do not represent specifically-defined facilities and processes. Rather, the costs are average estimates gathered from a literature search of available studies and pertain to generalized cost components. It must be emphasized that these costs have been developed solely for the purpose of determining the relative importance of the individual components. Different costs may result in different percentage weights and, therefore, a different assessment of the impact of the standard on total waste management costs. However, only radically-different weights will significantly change the economic impact estimates concluded by this analysis.

These costs are expressed on a unit cost basis -- dollars per kilogram of heavy metal for normalization purposes. Using total costs for each of the components would not be advisable since the different facilities required in the waste management program possess varying waste handling capacities and lifetimes of utilization. The best means of normalizing

TABLE 3

Cost Components for the Management and Disposal of Commercial Spent Fuel and the Expected Impact of Standard

Cost Component	Cost[a] ($/kg)	Percentage Distribution (%)	Impact of Standard on Cost Component
Storage	83	42.1	Covered by waste management operations standard -- expected to maintain status quo
Transportation	33	16.8	Not covered by standard
Encapsulation	11	5.6	Covered by both operations and disposal standards -- might have impact on encapsulation cost by affecting canister type
Disposal	42	21.3	Covered by both operations and disposal standards -- might have impact on cost of geologic disposal by influencing the choice of geologic medium
Research and Development	12	6.1	Standard may affect R&D cost by creating impact on site evaluation and increasing R&D for improved control technologies
Government Overhead	5	2.5	No impact expected
Decommissioning and Post-operational Activities	11	5.6	Not covered by standard

NOTE: These costs are based on the storage of spent fuel for ten years and disposal of the fuel in a geologic repository capable of retrievability.

[a] Costs are expressed in 1978 dollars (undiscounted).

the costs of waste management activities is to use the unit cost basis. Also, unit costs of waste management are more amenable than total costs to analyzing the effect on electricity prices and consumers' electric bills, the primary economic impacts of the commercial waste management program. The assumptions on total costs and units of waste handled that underlie the unit costs can be found in the references cited below.

Several studies have been made which provide estimates of the unit costs of waste management activities. Wide ranges in these cost estimates exist for some components due to the many uncertainties associated with a future program which is still in the planning stages and based on technology, some of which has not been demonstrated. The costs developed here represent what the costs of waste management will be at a time which is free from technological, political and administrative constraints. In other words, these costs assume that all facilities and services are operating according to proven technology and designed receipt rates of waste material, and also experiencing no effects from interruptions of operations due to administrative policies or unexpected fluctuations in demand.

The primary data source which was utilized was the TRW study performed for DOE (TRW 78) and which provided the input cost data for DOE's preliminary analysis of spent fuel-related charges (DOE 78b). The virtues of the TRW report are that it provides the necessary detail on waste management cost components that several studies lack and the scenarios which were examined relate very closely to the type of situation which the unit costs

in this document are assumed to represent, as explained above. This approach, referred to in the TRW report as the "venture methodology," addresses all the costs associated with constructing, operating, filling and decommissioning a single encapsulation and disposal facility. Since this methodology covers all the costs incurred throughout the entire economic life of the facility, issues such as the annual receipt rates of waste materials, unused capacity, and salvage value of unused portions of the facility need not be addressed. This scenario approximates a situation which is free from the effects of fluctuating demand and administrative constraints. However, the TRW study is designed to cover only the costs to the Government of its planned waste management program, and thus omitted other costs of the waste management process which are borne by the private sector but are subjected to the application of the EPA standard. Gaps in the TRW study were filled by using data from other references in order to generate a reasonable and complete categorization of costs which are relevant to analyzing the impact of the standard.

Since the activities included in the waste management process take place over a period of several years, the time value of money should be considered when deriving costs for the entire process. For the purpose of determining what portion of waste management costs might be affected by the EPA standard, it was assumed that values for the individual components should not be discounted but that their costs be weighted equally with regard to time. Utilizing undiscounted costs for this purpose appears to be reasonable considering that the impact under analysis is one that will take place in the future when all waste management activities will be

occurring simultaneously (involving different units of waste). The question of what activities are influenced by the standard thus pertains to a single point in time. Since discounting results in less importance attributed to those activities taking place at the end of the process (for a given unit of waste), it seems more reasonable to establish relative magnitudes of cost components by using undiscounted costs. When the issue at hand changes to determining the economic impact of the entire waste management process, then discounting should be included in the analysis since the impact is estimated by converting the cost to prices or one-time charges assigned to the unit of output of which the waste is a by-product, namely a kilowatt-hour of electricity. The one-time charge or price effect essentially takes place at the time the electricity is produced and must reflect the costs associated with handling the waste for a subsequent number of years. The concept of discounting is reflected in the methodology employed in the DOE spent fuel charge report and, therefore, is included in our estimates of the impacts of the reference program.

The basis for the estimated costs in Table 3 are described in the following paragraphs.

An extremely wide range of estimates exists for storage costs of spent fuel (assumed to be for ten years), according to the literature. The major source of this large divergence in cost is the assumption on whether storage takes place at the reactor site or at a centralized AFR facility, which is more expensive. The House Committee hearings revealed storage costs varying from $15 to $200 per kg (HRP 77, p.195). From the

TRW study, the unit cost of AFR storage is calculated by dividing the total undiscounted cost (excluding trust fund for decommissioning) by the total quantity of AFR shipments. This results in estimates of $154 and $175 per kg (1978 dollars) for the two cases which utilize an AFR facility (TRW 78, Tables A-2, A-3, A-6, and A-7). The Energy Information Administration (EIA) report to Congress assumed a cost of $60/kg (1978 dollars) for reactor-site storage (DOE 77a, Table 9-3). Other sources provided estimates of $50/kg (1976 dollars, APS 78, Table 16) and $80 to $150/kg (1977 dollars, ADL 77, p.188). Determination of an appropriate estimate was made by taking a weighted average of the unit costs of reactor-site storage and AFR storage, the former assumed to be $60/kg and the latter, $175/kg. The selection of the relative weights for the two types of storage was not a straightforward process. In the TRW report, the two cases which utilized an AFR facility assumed that approximately 19 and 29 percent of all spent fuel that was transferred to a repository were stored for variable lengths of time at an AFR facility. However, since the spent fuel was not stored at the AFR facility for the entire storage period the relative weight for AFR storage costs should be lower than these percentages. Also, the need for AFR storage arises from the fact that, in the absence of a repository for the waste, existing reactor-site storage is nearing capacity. Once the disposal facilities are on line and transfers are made from the reactor sites to the repository, the long-term need for an AFR facility diminishes. This situation is assumed in the DOE spent fuel charge report (DOE 78b) where in the reference case, AFR operations begin in 1983 and end in 1991. For the purposes of this paper, weights of

20 and 80 percent were assigned to AFR and reactor-site storage costs, respectively. Consequently the weighted average unit cost is $83/kg.

The transportation cost assumed in this paper is $33/kg, taken from the TRW report which estimated the cost of transporting spent fuel from an AFR storage facility to a repository (TRW 78, p.6-2). This assumption approaches the middle of the range of several estimates presented in the House Committee report (HRP 78, p.129) which was between $8 and $50 per kg.

The encapsulation cost was derived by taking the average of the undiscounted unit costs (excluding trust fund for decommissioning) of the encapsulation cost center from the two TRW "venture" scenarios (TRW 78, Tables A-2 and A-4, for units of spent fuel and Tables A-6 and A-8 for total undiscounted costs). The two unit costs were $10 and $11 per kg so that $11 was assumed to be the appropriate unit charge. This cost compares to a range of $8-14/kg (1977 dollars) estimated in the Arthur D. Little study, assuming carbon steel canisters (ADL 77, p.193). A study performed for the Natural Resources Defense Council (NRDC) assumed for the reference case encapsulation costs which also were $11/kg (MHB 78). Most of the other studies combined the encapsulation cost with the disposal cost.

The cost of waste disposal in a geologic repository with retrievability was estimated from the TRW report. Undiscounted unit costs (excluding trust funds for decommissioning and post-operational activities) were calculated for the two "venture" cases as $41 and $43 per kg. This source estimated costs of the repository assuming its location in underground salt

deposits. Costs include the mining, storing and backfilling of the salt, ventilating all shafts and tunnels, receiving of spent fuel shipments and emplacement of the canistered spent fuel in the repository while maintaining the retrievability. The average of the two costs, or $42/kg, was assumed for the waste disposal cost. This estimate is comparable to the (undiscounted) unit cost of $46/kg (1977 dollars) derived in the ADL study for retrievable storage in a geologic repository in bedded salt (ADL 77, Table B-23). The unit disposal costs used in the NRDC study (MHB 78), derived from the repository construction and operations costs in the reference scenario, was $53.5/kg. The majority of studies on waste disposal costs did not provide sufficient detail to determine their comparability with the above references. The cost based on the TRW study was used for consistency with the other cost components.

The costs of Government research and development and overhead were taken from the TRW report. R&D costs included in the study are those related to the considerations of alternative geologic media and are estimated at $520 million (1978 dollars), covering the period 1978 -- 1986. This estimate excludes the $40 million spent on R&D prior to 1978 since this cost has already been sunk, while there has been no attempt at forecasting R&D expenditures beyond 1986. Expressing this total cost on a unit basis is somewhat arbitary since it involves a judgment as to the number of units over which to spread this cost. The unit cost has been estimated here by taking the ratio of the $520 million to the total quantity of spent fuel handled in each of the four TRW scenarios (TRW 78, Table A-1). These ratios ranged from $8 to $14/kg; the average, $12/kg,

was assumed to be the R&D cost. Government overhead in the TRW report, defined as all non-R&D expenses to the Government not directly associated with the operation of the other cost centers (TRW 78, p.8-1), was assumed to be a constant annual expenditure, $13 million per year. Ranges of unit costs for each of the four scenarios were calculated by dividing this total annual cost by both the maximum and minimum quantities of spent fuel handled in any year throughout the time period (TRW 78, Tables A-2 through A-4). These ratios produced estimates ranging from $2 to $7/kg so that $5/kg was assumed to be the overhead cost.

Costs for decommissioning and post-operational activities of waste management facilities were also provided by the TRW study. These costs cover the activities associated with the encapsulation facility and the geologic repository. The cost of decommissioning the AFR storage facility was excluded due to the small relative share of this type of storage assumed in this paper. Decommissioning of reactor-site storage is closely related to the decommissioning of the reactor itself and is outside the scope of this analysis. Undiscounted unit costs were calculated for decommissioning and post-operational activities at the two facilities with the ratio for the two "venture" scenarios resulting in $10 and $12 per kg. The average, $11/kg, was assumed to represent this cost.

Based on the sum of these unit costs, the relative magnitude of each cost component in the waste management process was estimated. These relative shares are also indicated in Table 3. The most significant cost is storage, with a 42 percent share of the total costs. Disposal and

transportation costs account for 21 and 17 percent, respectively, while no other individual component represents greater than 6 percent of the total.

Several potential effects of the standard on waste management activities have been identified which may result in significant economic impacts. It is uncertain at this time whether these effects will in fact take place, so that it is possible the overall economic impact of the standard could even be zero. For the purpose of this analysis, however, each of the potential effects is assumed to occur. The potential effects of the standards are: (a) eliminating certain geologic media from consideration of repository sites, thereby affecting the cost of waste disposal; (b) influencing the selection of canister type; (c) forcing additional site evaluation than would otherwise be conducted; and (d) forcing additional research and development activities for improved control technologies. The primary basis for these impacts is the requirement of the radiation protection guidance that each of the barriers of the disposal system (as opposed to the overall disposal system) be designed to reduce releases as low as reasonably achievable. This requirement is expected to necessitate the selection of a very protective geologic medium, canister type and waste form, even though less protective barriers might comply with the numerical performance requirements of the standard.

Storage-related activities, although covered by the waste management operations standard, are not expected to be adversely affected by the standard. This part of the waste management process is an already ongoing activity as utilities, for the most part, have been storing their spent

fuel at reactor-site basins. The standard is not expected to have any impact on storage costs since the reactor-site storage experience indicates that no additional expenditures will be necessary for compliance. In the case of AFR storage, the cost of this planned facility already includes allowance for conforming with existing environmental standards as stated in the DOE spent fuel charge report: "Standards of construction, including environmental standards, would be commensurate with commercially licensed nuclear storage facilities" (DOE 78b, p.17). In other words, the EPA standard is expected to maintain the status quo with regard to the cost of storing spent fuel.

Government overhead costs are also not expected to be affected by the EPA standard. Transportation, decommissioning and post-operational activities are not covered by the standard so that there is no impact on those segments of the waste management process.

Each of the cost components can therefore be classified according to its relation to the standard in one of three ways: the component is not addressed by the standard; the component is addressed by the standard, but no impact on the cost is expected; and, it is addressed by the standard, and some impact can be expected. Three of the components -- encapsulation, disposal, and research and development -- fit the last category since it is EPA's judgment that the standard may influence the cost of waste management in the areas of canister selection (encapsulation), choice of geologic medium (disposal), and additional research for improved control technologies and site evaluation (R&D). The percentage shares indicated

in Table 3 show that approximately 22 percent of total waste management costs (transportation, decommissioning and post-operational activities) are not addressed by the standard. An additional 45 percent of the total cost (storage and Government overhead) is addressed by the standard, but on the basis of radiation protection experience in the nuclear industry, no impact on cost is expected. The result is that only 33 percent of the total waste management cost is expected to be influenced to some degree by the standard.

The following paragraphs describe the procedure by which the size of the standard's impact on the three affected cost components -- disposal, encapsulation and research and development -- was estimated. As stated at the outset of this paper, the uncertainty level of quantitative estimates pertaining to high-level waste management is extremely large so that accurate assessments of the standard's impacts are not possible at this time. However, based on the cost information that currently exists plus several judgmental assumptions, some simplified estimates can be made which at least place a range on the size of the impacts.

Disposal costs cover all the activities involved in constructing, operating and backfilling the geologic repository and represent 21 percent of total waste management costs. The standard may affect disposal costs by influencing the choice of geologic medium in which to place the repository. Therefore, the size of this impact was estimated by analyzing the relative costs of disposal for alternative media. DOE's commercial waste GEIS (DOE 79b) and its accompanying technology document (DOE 79c)

provided sufficient cost information in which to make this relative cost determination. In the GEIS, it is estimated that disposal costs, expressed on a levelized unit cost basis, for a repository in granite or basalt, the most expensive media, are 30 to 100 percent greater than disposal in salt, the least expensive medium and the medium assumed in the reference waste management plan (DOE 79b, p.3.1.134). Factors which are considered in this 30 to 100 percent relative cost range are the different fuel cycles, alternative values for the cost of capital, and different time frames for mining the repository (accelerated mining versus continuous mining). Consequently, if the standard effectively eliminates the use of salt as the medium for a repository, the maximum impact of the standard can be expected to approximate this range.

Encapsulation costs, which represent 6 percent of total waste management costs, may be affected by the standard to the degree that the standard may require a more protective canister than would otherwise be the case. The size of this impact has been estimated by first determining the relative cost of canisters produced from alternative metals and then by determining the percent of the total encapsulation cost that is represented by the cost of canisters. Unit costs for spent fuel canisters constructed of carbon steel, stainless steel, and titanium were presented in the ADL study cited earlier (ADL 77, p.193). These canister costs are in the ratio of 3:1 for stainless steel versus carbon steel, and 7.5:1 for titanium versus carbon steel. Cost information obtained from Battelle Pacific Northwest Laboratories, the contractor for DOE's GEIS, confirmed the relative cost factor for stainless steel versus carbon steel as their

estimates resulted in a ratio of about 3.5:1 (BNL 80). Based on the ADL relative cost factors, it is therefore estimated that canister costs, assuming carbon steel as the base case canister type (the assumption employed in DOE's GEIS), may increase by 200 to 650 percent due to the standard.

Besides the cost of canisters, the encapsulation cost component includes the cost of constructing and operating the encapsulation facility. Therefore, in order to estimate the impact of the standard on total encapsulation costs, we must know the percent of the encapsulation cost that is accounted for by the canisters. Estimates of this percentage were available, indirectly, from two sources -- the TRW study and the technology document which is the companion to DOE's commercial waste GEIS. Based on information presented in the TRW report (TRW 78, p.4-6) it was estimated that the canister cost represents about 10 percent of the total encapsulation cost. According to the cost estimates reported in DOE's commercial waste technology document (DOE 79c, p.5.7.91), the canister cost share of total encapsulation costs is expected to be 18 to 29 percent; the larger share pertains to Federal ownership of the facility and the smaller share assumes private ownership. Based on this information we have assumed a share of 20 percent.

Therefore, assuming that the canister cost represents 20 percent of the total encapsulation cost and that canister costs may be increased by 200-650 percent, it has been determined that the impact of the standard on the encapsulation cost may result in an increase of 40 to 130 percent.

Research and development costs appear to be the area where the standard may have its most significant impact in terms of the likelihood of occurrence but not necesssarily in the size of the impact since these costs represent only 6 percent of total waste management costs. We believe that the standard will affect the site evaluation for DOE's planned geologic repositories. It is possible that individual sites which are otherwise suitable may not possess the specific characteristics necessary for the site to comply with the disposal standard. Regardless of whether the standard would rule out a potential site for a repository, it may be assumed that the standard may have the impact of increasing R&D costs by forcing a closer examination of prospective sites before final selection. Also, more research and development on improved control technologies (e.g., more durable containers) might be required as a result of the standard. The size of the impact on this cost component which is attributable to the standard has been estimated on a purely judgmental basis. We have assumed that the standard will cause R&D costs to increase by 50 to 100 percent, the upper limit being a maximum impact which is probably an overstatement.

Based on these estimates of the size of the potential impacts and their relative share of total waste management costs, it is therefore concluded that the overall impact of the standard may result in an increase in total waste management costs of about 10 to 35 percent. As indicated above, though, the impact of the standard may in reality be zero if the conditions of the reference waste management plan are not affected; that is, if, after implementation of the standard, compliance can be met

by a repository constructed in salt, carbon steel canisters and no additional expenditures for site evaluation and research on control technologies. The percentage increase in total cost estimated in this analysis does provide a realistic range of the size of the impact of the standard, assuming that the impacts do materialize.

The economic impact of the EPA standard is assumed to have an incremental effect on the estimated impacts of the reference program. The EPA standard has been estimated as possibly increasing the total cost of waste management by about 10 to 35 percent. To determine the size of the incremental effect of the EPA standard, its expected impact should alternatively be stated in terms of the percentage increase in the charge to customers of nuclear-powered electricity which results from the incurrence of these waste management costs by utilities. Since a portion of the estimated total cost of waste management (spent fuel storage at reactor sites) is already included in electricity rates, the range of activities encompassed by the charge to utilities for waste management services provided by the Federal Government is smaller than the coverage of activities represented by total waste management costs. Consequently, the 10 to 35 percent estimates of the impact of the standard on total waste management costs need to be adjusted. The waste management charge to electricity customers is assumed to represent two-thirds of the coverage represented by the total cost of waste management activities. Therefore, the 10-35 percent increase in total costs, adjusted by this fraction, translates into approximately a 15 to 50 percent increase in the charge to consumers of nuclear-powered electricity, which could be attributed to the EPA standard.

An alternative, and more direct, method of estimating the impact of the standard on the reference waste management charge was also derived for comparison purposes. In DOE's recent environmental impact statement on the charge for spent fuel storage, the reference case spent fuel charge was broken down by individual cost components (DOE 80b, Table III.A.3). The costs of encapsulation, geologic repository, and research and development, were increased by the percentage changes estimated above to determine the overall effect of the standard on the total charge. This calculation resulted in an increase in the charge of 16 to 44 percent, which is very similar to the 15 to 50 percent estimated impact of the standard.

According to the analysis described in Appendix A and summarized in Section 3.2.1, the reference commercial waste management program has been estimated to result in a direct price increase in the national average residential electricity rate in 1990 of .4 to 1.4 percent. The EPA standard has been estimated as potentially resulting in an incremental increase of about 15-50 percent of this direct price effect. These two independent estimations together indicate that the maximum effect of the EPA standard will be an increase in the national average residential electricity rate of less than 1 percent. As also explained above, the total annual cost of the reference waste management program in 1990 (as reflected by the projected revenues to be collected from a waste management charge in that year and which excludes the cost of reactor-site storage of spent fuel) is estimated to range from about .5 to 1.2 billion dollars. Therefore, by increasing the waste management charge by 15-50 percent, the annual cost of the EPA standard in 1990 is estimated to range from about

75 to 600 million dollars, providing that the assumed impacts actually take place.

As mentioned at the outset of this paper, the economic analysis has been derived with the assumption that the EPA standard can be met by disposal in a geologic repository. If compliance with the standard cannot be met by geologic disposal, then either one of two types of economic impacts will probably occur. If the standard can be met by an alternative disposal method, such as sea-bed disposal, then price effects similar to those under a geologic disposal program may result (DOE 79b), but with an expected maximum upward deviation as large as a factor of 2 or 3 (times the .4-1.4 percent increase associated with the reference geologic waste management plan) (BNL 74). However, the costs of alternative disposal concepts have not been developed to a degree which would be considered reliable and useful for economic analysis. The second type of economic impact that might take place pertains to the impact on nuclear power growth and is addressed in the next section.

3.3 Impact of Standard on Nuclear Power Growth

The analysis developed in Section 3.2 and Appendix A emphasizes that a key factor in determining the size of the economic impact of the waste management program and the EPA standard is the relative importance of nuclear power in this country's future energy use. Therefore, an important area to investigate is the relationship of the standard to the future growth of the nuclear industry. The critical underlying issue to be determined is whether compliance with the standard is compatible with

the reference waste management plan. The analysis in Section 3.2 and Appendix A assumes that compliance with the standard is technologically feasible. If compliance with the environmentally acceptable standard is not feasible, then significant economic consequences can be expected to take place as the role of nuclear power in the generation of electricity will most likely diminish. If this situation is expected to occur, then an in-depth examination of the economic impacts, based upon postulated scenarios of the mix of nuclear power and alternative energy sources, would most certainly be required. Estimation of these impacts is beyond the scope of this project, but other studies (MA 77, PUF 79) have forecast significant economic disruptions resulting from a "non-nuclear" option.

Assuming that compliance with the standard is feasible, the analysis in Section 3.2 and Appendix A further assumes that the nuclear share of electricity generation is unaffected by both the reference waste management program and the EPA standard. The basis for this assumption lies in the belief that the cost of the reference program and the incremental cost of the standard is of a sufficiently small magnitude so that the relative costs of alternative power plants (i.e., coal versus nuclear) are not changed by the inclusion of these costs in the nuclear option. This belief is supported by the following two industry sources. The testimony of Mr. J. Edward Howard, Vice President, Nuclear, of Boston Edison Company, before a House Subcommittee investigating nuclear power costs (HRP 77), states:

> Although costs of waste management will differ depending upon whether or not reprocessing is permitted, the

> economic effects of waste management in either the reprocessing or throwaway fuel cycle is sufficiently small in relation to total power production costs so as to be nondeterminative in any decision-making regarding the nuclear option.

Researchers at Commonwealth Edison Company concluded much the same about waste management costs in an article on the economics of nuclear power (RO 78):

> ...the fuel cycle services the Government provides will be billed to the utilities without subsidy, like the enrichment services. Even if this estimate turns out to be 100 percent low, its impact on overall generation costs will not be enough to change the competitive position of nuclear power compared with coal.

The Department of Energy in their EIS on the spent fuel storage charge also concludes that "the nuclear decision is, on balance, considered to be unaffected by the fee..." (DOE 80b, Page II-10).

Although the analysis of this paper assumes no impact of the standard on the growth of nuclear power, a situation could result in which the standard might have a positive impact on the future expansion of the industry. If one assumes that an important obstacle affecting the growth of nuclear power is the public concern about radioactive waste disposal, then elimination of this obstacle might provide some stimulus to nuclear expansion. The public may perceive the EPA standard as providing sufficient protection from radiation exposure associated with the waste material so that this obstacle may, to some degree, be removed. If this conjecture were to hold, then the standard would be responsible for a positive impact on nuclear power growth. To the degree that the standard results in the

substitution of "less costly" nuclear systems for "more costly" fossil fuel systems, substantial economic benefits may be realized. However, because of the uncertain likelihood of the EPA standard eliminating public concern and affecting utility decision-making, this potential impact cannot be determined at this time.

4. MILITARY WASTE MANAGEMENT

4.1 Overview

Analyzing the economic impact of the EPA standard on the military waste management program involves limitations beyond those associated with the commercial waste program. Even before one attempts to estimate the incremental impact of the standard, limitations are encountered in assessing the economic impact of the military waste management program itself. These limitations stem not only from the difficulty in specifying a "baseline" waste management program, which we have seen is also characteristic of the commercial waste management program, but, in addition, from the "public good" nature of the military waste program.

The military waste management program is the result of the development of nuclear weapons used for national defense purposes. National defense is termed a "public good" which implies that all members of the population benefit from its use, and that one individual's consumption of the good does not affect another individual's consumption. The provision of the good is made by the Government and financed by tax revenues in order to provide benefits to the general population. The public-good nature of the military waste management program thus makes it impossible to identify individual segments of the general population who are affected by this program and its accompanying expenditures. This situation is the opposite of the commercial waste management program in which the producers and consumers of nuclear power -- the activity both generating the waste material and which has financial responsibility for the waste management

expenditures -- can be identified and in which a microeconomic analysis can be performed. In the case of military waste, only a macroeconomic analysis can ideally be developed, and that is limited to the extent that cost and public finance information as well as analytical tools, such as macroeconomic models, are available.

Unfortunately, the relevant information necessary for a macroeconomic impact analysis of the military waste program is not available, the consequence of a program whose stage of financial planning has lagged behind its commercial counterpart. In the Department of Energy documents which have addressed the costs of military waste management alternatives (DOE 77b, DOE 77c and DOE 78c), and in other DOE actions to date, no attention has been focused on how the required expenditures will be financed. Preliminary project cost estimates on the different alternatives have been the only economics-related information which has been generated. Information such as the time-frame over which these expenditures can be expected to be incurred as well as the impact on the Federal budget as a result of the program, needs to be developed before the economic impact of the program can be estimated. Therefore, very few conclusions about the economic aspects of the program, as well as the incremental impact of the EPA standard, can be forthcoming at this time.

This chapter is organized into two major sections which pertain to the two types of military waste material that are covered by this standard -- high-level waste and transuranic waste. Section 4.2 addresses the

management of high-level waste and estimates the economic impact of the standard. Section 4.3 covers the management of transuranic waste.

4.2 High-Level Waste

4.2.1 The Cost of High-Level Waste Management

Cost information on the military high-level waste management alternatives was furnished by DOE and is shown in Table 4. These numbers represent DOE's best estimates, but it should be noted that these estimates are based on preliminary engineering designs which, according to DOE, are expected to change significantly. Estimates were provided for each of the three military waste sites (Savannah River, Hanford, and Idaho Falls) and for four different waste management alternatives. These alternatives include the continuation of the present storage mode, conversion of the waste material to glass and disposal in an onsite surface facility, conversion to glass and onsite geologic disposal, and conversion to glass with offsite geologic disposal. Technically speaking, the costs for individual sites cannot appropriately be summed together since DOE cautions that they are based on different levels of engineering concepts, but for the purposes of this paper it was felt that little distortion would result from this summation.

The waste inventories upon which these costs are based are also quite different. Costs for high-level waste management at Hanford pertain to the inventory of accumulated waste through 1971. The Savannah River estimates are based on a projected 1985 inventory of waste while the costs

TABLE 4

Estimated Total Cost of Defense High-Level Waste Management Alternatives[a/]

(Millions of 1978 Dollars)

Alternative	Savannah River	Hanford	Idaho Falls	Total
Continue Present Storage	296	624	5 [b/]	925
Convert to Glass, Onsite Surface Disposal	2138	1603	370	4111
Convert to Glass, Onsite Geologic Disposal	1770	1705	217	3692
Convert to Glass, Offsite Geologic Disposal	1795	1780	376	3951

[a/] Operating and capital costs do not include full recovery costs for the geologic repository.

[b/] Annuity for routine surveillance.

Source: Letter from Sheldon Meyers, DOE, to James E. Martin, EPA, March 12, 1979.

for Idaho Falls assume quantities of waste expected to be accumulated by the year 2000.

As Table 4 indicates, the total cost for the three disposal alternatives (excluding the status quo option) ranges from $3.7 billion for onsite geologic disposal to $4.1 billion for onsite surface disposal, with offsite geologic disposal estimated at $4.0 billion. The maximum variation in cost is relatively small, approximately 10 percent. However, it should be mentioned that the selected waste management alternative may differ for the individual sites. On an individual site basis, the maximum relative spread in the cost of waste management alternatives was 21 percent for Savannah River, 11 percent for Hanford and 73 percent for Idaho Falls. The impact of the relatively wide range for Idaho Falls on the combined sum for the three sites is diminished by the fact that its total expenditures are much smaller than those for the other two sites. For a given alternative, the cost at Idaho Falls is only 13 to 23 percent of the estimate for Hanford. Consequently, even if different alternatives are selected for the individual sites, the variation in the total cost of military waste management appears at this time to be very small. This conclusion assumes that the alternative of continued storage in the present mode is an unacceptable long-term waste management alternative. As Table 4 shows, the total costs for any of the three disposal alternatives is higher than the cost of maintaining the status quo by about a factor of four.

As discussed above, very little can be said at this time about the economic impact of the military waste management expenditures. Total

costs have been presented for military waste management rather than unit costs, as in the case of commercial waste management, since there is no meaningful economic unit in which to express the economic impacts, such as a kilowatt-hour of electricity. However, if these costs could be expressed on an annual basis, they could then be related to the nation's Gross National Product (GNP), the budget outlays of the Federal Government, or the budget outlays of the Department of Energy to gain some perspective as to their relative importance. The information necessary to do so in a judicious manner is generally not available, but if we make some simplified assumptions, the task can be accomplished. If we assume that these total costs, about 4 billion dollars, are intended to be spent over a period of 10 years, then the average annual cost is roughly $400 million (time value of money considerations aside). In fiscal year 1978, the budget outlays for DOE were 5.9 billion dollars (ERP 79). Therefore, the annual outlays for military waste management would represent about 7 percent of the FY 1978 DOE budget. For comparison purposes, the $400 million annual cost of military waste management would represent .089 percent of FY 1978 budget outlays for the Federal Government and .019 percent of the 1978 GNP (ERP 79). If the assumption is changed so that the costs of waste management pertain to 15 years, the average annual expenditure would be about 4.5 percent of the DOE outlay for FY 1978. An investigation in much greater depth is necessary before a degree of significance can be attributed to these expenditures, as well as a determination of their economic consequences.

4.2.2 Impact of Standard

The economic impact of the standard on the military high-level waste management program was estimated in a manner similar to the procedure followed for commercial waste, even though the results could not be stated in as detailed a fashion due to the inherent limitations of the analysis, discussed above. First, a reference waste management plan was assumed in which the individual cost components and their values were specified. Second, the potential impacts of the standard on this reference program were identified. Third, the size of each of the impacts was estimated to the degree possible. Finally, these estimates were summed to determine the overall impact of the standard on the total cost of the reference program. Since the financing plans for the expenditures required by the military waste program have not yet been developed, very little can be said at this time about the economic consequences of the reference program or the incremental effect of the standard on the program.

Selecting a reference military waste management plan for evaluating the economic impact of the standard requires judgment as to actions which might occur in the absence of the standard. Three alternatives appear credible: (a) long-term surface or near-surface storage at the three existing high-level waste sites; (b) geologic disposal, onsite; and (c) geologic disposal, offsite. From EPA's experience with the public workshops on criteria for radioactive waste management, it is felt that there is sufficient sentiment against option (a) so that it is very unlikely that this option will occur, even if the EPA standard is not implemented. Both options (b) and (c) have received significant attention,

but given past concerns about the transportation of radioactive wastes, we feel that onsite geologic disposal would be the most likely course of action without the standard. Therefore, the reference military high-level waste management plan assumed for this analysis is the operation of an onsite geologic repository at each site.

Table 5 presents the estimated total cost of the reference high-level waste management program detailed by individual cost component. The estimates are based on data presented in DOE defense waste documents and a response by DOE to an EPA request for cost information (DOE 78c, DOE 77b, DOE 77c, DOE 79a). As discussed earlier, these estimates contain a high degree of uncertainty and are expected to change substantially as refinement of the waste management program proceeds. The individual cost components are waste retrieval, processing (which includes the costs for radionuclide removal, decontaminated salt disposal, and immobilization), canisters, transportation, storage/disposal, research and development, and decommissioning. As Table 5 indicates, the processing cost is by far the largest cost component, accounting for 60 percent of the total cost of 3.7 billion dollars.

Five potential impacts of the standard have been identified and pertain to each of the cost components of Table 5 except waste retrieval and decommissioning. First, the standard may influence the cost of processing waste by requiring the separation of long-lived technetium-99 for disposal. In the reference program, technetium-99 would be left in processed salt cake and stored in existing on-site tanks. Second, the

TABLE 5

Cost Components for Reference Defense High-Level Waste Management Program - Glass, Onsite Geologic Disposal

(Millions of 1978 Dollars)

Cost Component	Cost	Percent of Total Cost
Waste Retrieval	233	6.3
Processing	2204	59.7
Canisters	198	5.4
Transportation	27	0.7
Storage/Disposal	456	12.4
R&D	311	8.4
Decommissioning	263	7.1
TOTAL	3692	100.0

standard may affect the canister cost by requiring a more restrictive canister. Third, transportation costs may be significantly affected by the standard if the standard eliminates the onsite disposal alternative and requires wastes to be disposed in an offsite repository. Fourth, the disposal cost may be affected by the standard if the selected geologic media are more expensive to mine than the media assumed in the base case. Fifth, research and development costs may be increased by requiring more extensive site evaluation to take place and more research for improved control technologies.

The impact on high-level military waste processing due to the standard requiring the separation of Tc-99 has been estimated to result in a 10 percent increase in the reference processing cost. This estimate is based on discussions with scientists specializing in this type of technology. Based on the processing cost presented in Table 5, the size of this impact is estimated at approximately $220 million.

The impact of the standard on the cost of canisters was estimated in a manner similar to that employed for commercial high-level waste in which the cost of alternative metals was compared to a reference canister type. The canister cost of Table 5 reflects the use of carbon steel canisters for the waste at the Hanford site and stainless steel canisters for Savannah River and Idaho Falls. Using the same cost factors relating carbon steel, stainless steel, and titanium canisters, that were assumed in the commercial waste encapsulation analysis, the impact on canister cost was estimated by assuming, first, the use of only stainless steel

canisters at all sites and, second, the use of titanium canisters at each site. This calculation resulted in an incremental impact over the reference canister cost of 160 to 697 million dollars. The percentage impact on this cost component is different than that for the commercial waste encapsulation cost since it includes only the cost of the canisters themselves and not the cost of constructing and operating the encapsulation facility. The relative impact is also different because, for commercial waste, carbon steel was assumed to be the reference canister type for all canisters.

The impact of the standard on transportation cost was estimated by assuming the differential in transportation costs between the onsite and offsite geologic repository scenarios of the DOE reports (DOE 78c, DOE 77b, DOE 77c, DOE 79a). This differential was 322 million dollars.

The standard's impact on storage/disposal cost was assumed to range from 0-30 percent. In the commercial waste analysis, it was stated that the maximum cost differential for alternative geologic media is 30-100 percent, representing the disposal cost differential for a repository constructed in basalt versus salt. This differential is not appropriate for military disposal costs since salt is not the reference medium for any of the three military waste sites. The impact of the standard on storage/ disposal cost is therefore estimated to range from zero to $137 million.

The impact of the standard on R&D costs is assumed to be the same as that for the commercial program, namely an increase of 50 to 100 percent.

Based on the estimate of R&D costs contained in Table 5, this impact is assumed to result in an increase of 156-311 million dollars.

Combining all the estimates of the individual impacts yields the result that the overall impact of the standard on the total cost of military high-level waste management is expected to range from .9 to 1.7 billion dollars. Compared to a reference onsite geologic disposal program costing $3.7 billion, the standard's impact may result in a cost increase of 23 to 46 percent. As discussed in the commercial waste section, this estimate assumes that each of the impacts identified above will actually take place. To the degree that these impacts do not materialize, the impact of the standard will be diminished.

4.3 Transuranic Waste

Transuranic (TRU) waste is defined as material containing more than ten nanocuries of transuranic activity per gram of material (IRG 79). TRU wastes result primarily from the reprocessing of spent fuel and the fabrication of plutonium in nuclear weapons production. In light of the deferral on reprocessing, virtually all of the existing TRU waste has been generated from weapons production and is, therefore, a component of military waste management.

TRU waste from weapons production exists in a buried or retrievably-stored form at several DOE sites, as shown by Table 6. As of January 1977, the inventory of accumulated DOE TRU waste totalled nearly 15 million cubic feet, of which 88 percent is buried while 12 percent is

TABLE 6

Existing DOE TRU Waste

(Millions of cubic feet as of 1/1/77)

Site	Buried Waste[a]	Retrievably Stored Waste[b]
Hanford, WA	5.40	0.27
Idaho Falls, ID	2.30	1.28
Los Alamos, NM	4.10	0.06
Oak Ridge, TN	0.20	0.05
Savannah River, SC	1.00	0.06
Nevada Test Site	0.01	0.01
TOTAL	13.00	1.72

(a) These are approximate volumes of TRU waste included in the buried low-level waste. Burial of DOE TRU waste ceased in 1974 (most sites in 1970).

(b) Does not reflect any potential volume reduction.

Source: Report to the President by the Interagency Review Group on Nuclear Waste Management, March 1979, p.D-17.

in retrievable storage. Of the total that is buried, 42 percent is at the Hanford site, 32 percent at Los Alamos and 18 percent at Idaho Falls. Approximately 74 percent of the total retrievable TRU waste is located at Idaho Falls, while Hanford accounts for an additional 16 percent.

Long-term waste management plans for TRU waste are currently being developed by each of the sites. Two sites -- Idaho Falls and Savannah River -- have produced alternatives documents which have been prepared to further aid in the formulation of a waste management plan (DOE 79d, DOE 79e). These reports pertain to the management of TRU waste in retrievable storage only. As in the case of high-level waste, both commercial and military, these plans are a long way from being implemented. Nevertheless, these documents provide rough estimates of projected quantities of TRU waste and the costs involved in their "management." It is expected at this time that TRU waste will be disposed of in a manner similar to high-level waste, namely, in a geologic repository. Therefore, the range of costs presented here covers only the geologic disposal alternatives, both onsite and offsite, and does not consider other alternatives such as surface storage. All cost estimates are preliminary in nature and may vary substantially due to the high degree of uncertainty.

The volume of TRU waste retrievably stored at Idaho Falls is projected to reach 2 million cubic feet by 1985, an increase of about two-thirds over the 1977 inventory. Costs for the alternatives which include offsite geologic disposal of TRU waste are estimated to range from 756 to 778 million dollars. These costs cover the activities involved in waste retrieval,

processing (which includes incineration and immobilization by slagging pyrolysis), packaging, shipment and disposal of TRU waste (alternatives 3, 4 and 6). Estimated costs for alternatives which include the same method of retrieval and processing but involve disposal in an onsite geologic repository (alternatives 5a and 5d) are 801-807 million dollars.

The amount of retrievable TRU waste at Savannah River is projected to double by 1990, reaching 122,000 cubic feet. Waste management alternatives covering retrieval, processing, packaging, shipment and disposal in an offsite geologic repository (alternatives 4 through 9) are estimated to range in cost from 184 to 221 million dollars. The cost for the same alternatives but with onsite geologic disposal are estimated at 290-327 million dollars. It is stated in the report that the reason for the onsite disposal alternatives being more costly than offsite disposal is that all the costs are borne by Savannah River in the former case while in the latter case disposal costs are shared by several sites. However, since the complete cost of offsite disposal may not be reflected in the assumed "payment fee," this comparison of onsite/offsite waste management costs may be misleading. More detailed and definitive cost information is required in order to make such an assessment.

The EPA standard applies to TRU wastes which contain more than 100 nanocuries of transuranic activity per gram of waste. Therefore, the standard, by definition, covers the waste management activities of only a portion of the quantities of TRU waste discussed above.

The impact of the standard on TRU waste management cannot be determined at this time. Following the same procedure used in estimating the impact of the standard on high-level waste management is not possible due to the very high degree of uncertainty which is characteristic of the TRU waste management program. Specifying a reference waste management plan with detailed cost components requires more information than is presently available, and identifying the impacts attributable to the standard and estimating their size would be sheer speculation.

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APPENDIX A

METHODOLOGY FOR ESTIMATING THE ECONOMIC IMPACT OF THE COMMERCIAL WASTE MANAGEMENT PROGRAM

A.1 Overview

This section discusses the methodology used in estimating the economic impact of the waste management program. The methodology is presented in a generalized form so that it is applicable to analyzing impacts resulting from any increase in the cost of nuclear-powered electricity, regardless of the cause. The starting point for this estimation procedure is the unit cost, expressed in mills per kilowatt-hour, which can be attributed to the program under investigation. The impacts estimated in this section are normalized and correspond to a cost increase of 1 mill/kwh. The impacts are proportionally related to the unit cost so that impacts from a program can be determined by means of scaling the normalized impacts by the relative proportion of the unit cost under analysis to the normalized unit cost.

The procedure employed to estimate the economic impacts focuses on measuring the direct effect on consumers, namely the expected increase in electricity rates to residential customers. The increase in cost affects the utility by raising its total revenue requirements. As discussed below, this impact is determined by assuming the complete pass-on of the cost to the customers. In response to the impact on revenue requirements, an increase in the rate charged to residential customers is estimated. Studies prepared for the Federal Government and the electric utility

industry (TBS 77, PE 75) both assume that the increase in rates for each type of customer will be equal to the percentage increase in total revenue requirements. Since residential and commercial customers have higher average rates than industrial users, the absolute increase in their rates is greater.[1] An estimate of the absolute increase in the average monthly residential bill is then derived by multiplying the absolute increase in the residential rate by an estimate of the average monthly usage. This absolute increase is then compared to an estimate of the average bill in effect without incurring the cost of the program under investigation, to obtain the relative impact. Finally, and most importantly, the impacts are adjusted for coverage of the industry affected by an increase in the cost of nuclear power, namely, the percent of electricity generated from nuclear power plants.[2]

A review of several studies analyzing the economic impacts of pollution controls on the electric utility industry (TBS 76, TBS 77, PE 75, PE 76, TA 73, CEQ 72) shows that a convention exists whereby costs to utilities are assumed to be passed on entirely to their customers. These studies indicate that this is a relatively safe assumption in light of the fact that the industry is composed of regulated monopolies.

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[1]In 1977, average revenue per kilowatt-hour (expressed in 1977 dollars) was 37.8 mills for residential, 38.4 mills for commercial and 23.3 mills for industrial users, with the average for all customers (including street and highway lighting, other public authorities, and railroads) being 32.1 mills (EEI 77).

[2]See Table A-2 for a detailed explanation of the estimation procedure.

However, as one source (CEQ 72) explains, in reality, state regulators sometimes do not allow the utilities to wholly pass on their cost increases to its customers and, depending on the nature of the increase, they may decide that it should be shared among both the customers and the company's stockholders, in which case the utility would merely absorb some portion of the increased cost. Consequently, the convention of wholly passing on costs to customers is a worst-case assumption (with regard to measuring direct impacts on consumers), and one that is used in this paper.[1]

Another related issue of importance is the fact that rate increases granted by the State commissions will generally take place after the increased cost has already been incurred so that, depending on the degree of "regulatory lag," some amount of time will elapse before an "equilibrium" position is reached. There is evidence that for the last several years this lag is increasing (TEK 80). This consideration, though, is not too significant for this analysis due to the long-run nature of the waste management situation and its inherent lack of a need for fine-tuning, stemming from the many uncertainties associated with the program and the cost estimates.

In addition to the direct impacts calculated on both a national and regional level, secondary impacts on consumers from higher electricity

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[1]The impact of the waste management charge on individual utility cash flows and stockholders' rate of return will depend on the treatment of this incremental cost by state public utility commissions. Based on the small size of this charge, it appears that these potential effects will be insignificant even if the entire cost is not passed on to customers.

rates are also addressed. These impacts pertain to the effect on the prices of all goods and services resulting from an increase in the price of electricity (charged to commercial and industrial users). Also, total annual expenditures resulting from a 1 mill/kwh increase in the cost of nuclear-powered electricity are estimated on a nationwide basis.

A.2 National Impact Analysis

The increase in the cost of nuclear power is related to the revenue requirements of the utilities in order to make an economic evaluation of the impact of the additional cost under investigation. Total revenue requirements reflect the total cost of producing electricity (TBS 77, EPA 76). Revenues cover both capital and operating costs, as well as a rate of return for investors, and conveniently combine all these elements into a single measure. Also, revenue requirements reflect the amount that customers will actually pay (assuming 100 percent of the cost is passed on to customers) for waste management activities. An increase of 1 mill/kwh for the unit cost of waste management translates into a 1 mill/kwh increase in the total revenue requirement of nuclear power plants. Average revenue per kilowatt-hour in 1977 for all customers (and all types of generating plants) was 34.5 mills (expressed in 1978 dollars, per DOE 78, Table 16-5). Since the activities under analysis pertain to a future technological process rather than an existing program, economic impacts have been estimated for a future date at which time presumably the waste management program will already have been instituted, and the country's nuclear capacity will have been expanded. The year 1990 has been selected.

Estimation of future economic impacts requires a baseline forecast of several key parameters. Among these are the following:

-- Real price of electricity

-- Price elasticity of demand for electricity

-- Consumption of electricity

-- Relative share of electricity generation by nuclear power

The relationship of these forecasted parameters to the size of the economic impacts is relatively straight-forward. The higher the rate of growth in the real price of electricity the smaller is the relative impact of waste management. The greater (in absolute value) the price elasticity, the smaller the increase in the customer's bill due to a waste management charge.[1] The higher the level of electricity consumption, the larger the absolute impact on the customer's bill (relative impact remains the same, regardless of the amount of electricity consumed.) Finally, the greater the share of electricity generated from nuclear power, the larger the economic impact of waste management.

Because an evaluation of the impacts is so dependent on these parameters, care was taken in developing the assumptions for their projected values. Two sets of assumptions were devised for analyzing the impacts, a

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[1]This holds for elasticities in the range of 0 to -1. For elasticities greater (in absolute value) then -1, the greater the price elasticity the larger the decrease in the customer's bill, attributable to a price increase. See page A-7 for an explanation of the relationship of price elasticity to total revenue (price times quantity) or, in this case, the customer's electric bill.

"maximum impact" case and a "realistic" case. The "maximum impact" scenario assumes a forecast for each parameter that would maximize the economic impact of the waste management program. None of the assumptions are likely to occur let alone all four simultaneously. The "realistic" case is based on independent estimates for each parameter that are typically categorized as "most likely" or "middle-of-the-road." Table A-1 presents the assumptions used in each case. A brief review of the basis for each assumption is presented next.

Over the period 1950-1970, the real price of electricity[1] decreased each year. Beginning in 1971, this trend has been reversed as (with the exception of 1973) the real price has been rising steadily. In the maximum impact scenario, we have assumed no growth in the real price of electricity, or alternatively stated, that the total revenue requirement and the residential electricity rate in 1990 (expressed in 1978 dollars) assume the values for the base year 1977. For the realistic case, an average annual growth rate of 0.5 percent is assumed for the price of residential electric power while the total revenue requirement is assumed to increase at an annual rate of 0.8 percent, based on recent projections from the Department of Energy (DOE 78, Table 16-5).

Price elasticity of demand measures the degree of sensitivity that consumers have with regard to the amount of a product purchased and the

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[1]As measured by the ratio of the consumer price index (CPI) for electricity to the CPI for all items.

price charged for the product. In simple terms, the elasticity is expressed as the ratio of the percentage change in quantities purchased to the percentage change in the price. The price elasticity in most situations is a negative number, which reflects the inverse relationship of price changes and quantities demanded (assuming a down-sloping demand curve). In the price elasticity formula, though, a minus sign is inserted before the ratio in order to make the elasticity number positive. This is done for convenience in discussing elasticities. However, empirical studies generally refer to the price elasticity as a negative number which is directly estimated from a regression analysis (see TA 75). For this reason, discussion of price elasticity estimates in this paper will treat the measure as a negative number, but statements about the size of the elasticity will pertain to the absolute value of the number.

A price elasticity between 0 and -1, referred to as inelastic, implies that in response to a price increase, consumption will be somewhat diminished but that the total revenue from the sale of the good, namely the product of the price and quantity, will be increased. This stems from the fact that the percentage increase in price is greater than the percentage decrease in quantity demanded. An elasticity greater (in absolute value) than -1, called elastic, means that both the quantity demanded and the revenues generated will decrease as a result of a price increase since the percentage increase in price is less than the percentage decrease in quantity demanded.

TABLE A-1

Assumptions Used for Projected

National Average Economic Impacts of Waste Management

Parameter	Maximum Impact Case	Realistic Case
Growth in Real Price of Electricity(a)		
Residential Rate	0	0.5%
Total Revenue Requirements	0	0.8%
Price Elasticity of Demand for Electricity	0	-0.2
Growth in Consumption of Electricity (kwh per Residential Customer)(a)	5%	1.3%
Relative Share of Electricity Generation by Nuclear Power, 1990	33%	22%

(a) Average annual growth rate, 1977-1990

Note: Base year values are:
- Total revenue requirements, 1977=34.5 mills/kwh (1978 dollars)
- Residential electricity rate, 1977=40.6 mills/kwh (1978 dollars)
- kwh per residential customer per month, 1977=724.

The source for the total revenue requirement and the residential electricity rate is Department of Energy, Energy Information Administration, Annual Report to Congress 1978, Volume III, Table 16-5. Monthly residential consumption for 1977 was derived from the annual estimate found in Edison Electric Institute, Statistical Yearbook of the Electric Utility Industry for 1977.

Several studies of the price elasticity of demand for electricity have been made (TA 75) and much of the empirical evidence to date has indicated that the long-run elasticity[1] may be as high as -2. However, the studies of the economic impacts of utility pollution regulations cited earlier (TBS 77, PE 75) assume that the price elasticity is zero. For the maximum impact scenario, a zero price elasticity was chosen, thereby assuming that one's demand for electricity is not affected by the change in price. In this case, the relative impact on the electric bill is the same as the relative impact on the price of electricity. For the realistic case, an elasticity of -.2 was assumed, based on the DOE analysis contained in their annual report to Congress (DOE 78, Table A-2b).

The level of consumption of electricity in the future is a key determinant of the size of the absolute impact on the consumer's electric bill, but does not affect the relative impact. Based on forecasts from DOE (DOE 78, Tables 16.3 and 17.1), a growth rate of 1.3 percent per year in kilowatt-hours per residential customer was used in the realistic case (based on a 1977-1990 average annual rate of 3.16 percent for total residential kwh and 1.85 percent for total number of households-assumed to equal the number of residential customers). For the maximum impact case, an annual growth rate of 5 percent was assumed, the rate assumed in the analysis performed in 1975 by National Economic Research Associates, Inc. (PE 75). The long-term historical annual growth rate in kwh per

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[1]Long-run elasticities are generally greater (in absolute value) than short-run elasticities since purchasing behavior in response to price changes can be altered more easily over time.

residential customer, as measured over the period 1957-1976, was 5.2 percent. However, this rate of growth has diminished significantly the last few years. From 1970 through 1976 the average annual rate was 2.8 percent. Consequently the use of the 5 percent growth rate for the forecast is consistent with the intent of the "maximum impact" scenario.

The importance of the relative share of electricity generated by nuclear power in the analysis is obvious. For the realistic case, the 1990 share projected by DOE's midcase forecast was assumed -- 22 percent, up from about 12 percent in 1977 (DOE 78, Table 12-3). The installed nuclear capacity assumed in this forcast is 152 GWe. For the "maximum impact" case, a nuclear share of 33 percent was assumed. This represents the relative share estimated by DOE in their "nuclear ordering upswing" scenario for the year 1995 and implies a nuclear capacity of 269 GWe (DOE 78, Table 12-6). Assuming DOE's 1995 nuclear forecast for 1990 is also consistent with the purpose of the maximum impact scenario.

Applying the assumptions of Table A-1 to the base year values of the parameters and following the procedure outlined earlier, one can derive the absolute and relative impacts on the national average residential electricity rate and monthly residential electric bill in 1990. Under the maximum impact conditions, the average rate is estimated to increase by .39 mills/kwh or 1.0 percent, while the average monthly residential bill should rise by $.53, also 1.0 percent. For the realistic case, the expected impacts are a 0.6 percent rise in the national average rate or .25 mills/kwh, and an increase in the monthly electric bill of $.17 or

0.5 percent. Table A-2 presents the calculations used in estimating the direct economic impacts for each case.

In addition to estimating the economic impacts of the commercial waste management program in terms of the effects on electricity prices and customers' electric bills, an estimate was made of the total cost represented by a 1 mill/kwh charge on nuclear power generated in 1990. This estimate should provide a measure of the annual cost of the program. The estimate was derived by utilizing assumptions about the following parameters: total electricity generation, percent of electricity generation provided by nuclear power, total electricity sales, and the total revenue requirement. A single set of assumptions was developed which corresponds to the "realistic" scenario discussed above.[1] Based on these assumptions, the total cost of a 1 mill/kwh charge levied on nuclear power generated in 1990 is estimated to be $825 million or 0.6 percent of total revenues of $130 billion.

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[1]The assumptions used in the estimating procedures are as follows:

1. Total electricity generation: 2124 billion kwh in 1977 (EEI 77, Summary) and an annual growth rate of 4.4 percent for the period 1977-1990 (DOE 78, Table 16-3).

2. Nuclear share of electricity generated in 1990: 825 billion kwh or 22 percent of total generation (DOE 78, Table 12-3).

3. Total electricity sales: 1951 billion kwh in 1977 (EEI 77, Summary) and an annual growth rate of 4.3 percent for the period 1977-1990 (DOE 78, Table 16-3).

4. Total revenue requirement: 34.5 mills/kwh in 1977 and 38.3 mill/kwh in 1990, which corresponds to an annual growth rate of 0.8 percent (expressed in 1978 dollars per DOE 78, Table 16-5).

TABLE A-2

Summary of Calculations Used in Estimating National Impact (Direct) in 1990 of a 1 Mill/Kwh Unit Cost of Waste Management

Absolute increase in residential electricity rate (Δ rr) equals:

$$\frac{MC_{wm}}{RR_{1990}} \times rr_{1990} \times \%NUC$$

where $RR_{1990} = RR_{1977} \times (1+RRGR_{1977-90})^{13}$

$rr_{1990} = rr_{1977} \times (1+rrGR_{1977-90})^{13}$

Relative increase in residential electricity rate (%rr) equals:

$$\frac{\Delta rr}{rr_{1990}}$$

Absolute increase in monthly residential electric bill (Δ MEB) equals:

$$MEB_{mc,1990} - MEB_{1990}$$

where $MEB_{1990} = rr_{1990} \times (1+KWHGR_{1977-90})^{13} \times KWH_{1977}$

$MEB_{mc,1990} = (rr_{1990} + \Delta rr) \times \{(1+KWHGR_{1977-90})^{13} \times KWH_{1977} \times [1+(E_d \times \% rr)]\}$

Relative increase in monthly residential electric bill (%MEB) equals:

$$\frac{\Delta MEB}{MEB_{1990}}$$

Symbols:
- RR = Total revenue requirements (mills/kwh)
- rr = residential electricity rate (mills/kwh)
- RRGR = Average annual growth rate of total revenue requirement (percent)
- rrGR = Average annual growth rate of residential electricity rate (percent)
- MC_{wm} = Unit cost of waste management (mills/kwh)
- %NUC = Relative share of electricity generated by nuclear power (percent)
- MEB_{mc} = Monthly residential electric bill, as a result of unit cost (dollars)
- MEB = Monthly residential electric bill, without unit cost (dollars)
- KWHGR = Average annual growth rate of monthly electricity consumption per residential customer (percent)
- KWH = Monthly electricity consumption per residential customer (kwh)
- E_d = Price elasticity of demand for electricity

Maximum Impact Case	Realistic Case
$RR_{1990} = 34.5x(1+0.0)^{13} = 34.5$ mills/kwh	$RR_{1990} = 34.5x(1+.008)^{13} = 38.3$ mills/kwh
$rr_{1990} = 40.6x(1+0.0)^{13} = 40.6$ mills/kwh	$rr_{1990} = 40.6x(1+.005)^{13} = 43.3$ mills/kwh
$\Delta rr = \frac{1.0}{34.5} \times 40.6 \times .33 = .39$ mills/kwh	$\Delta rr = \frac{1.0}{38.3} \times 43.3x.22 = .25$ mills/kwh
$\%rr = \frac{.39}{40.6} = 1.0$ percent	$\%rr = \frac{.25}{43.3} = 0.6$ percent
$MEB_{1990} = 40.6x(1+.05)^{13}x724 = \$55.43$	$MEB_{1990} = 43.3x(1+.013)^{13} \times 724 = \$37.08$
$MEB_{mc,1990} = (40.6 + .39) \times ((1+.05)^{13} \times 724 \times [1+(0x.01)]) = \$55.96$	$MEB_{mc,1990} = (43.3+.25)x \{(1+.013)^{13} \times 724 \times [1+(-.2 \times .006)]\} = \$37.25$
$\Delta MEB = \$55.96 - \$55.43 = \$.53$	$\Delta MEB = \$37.25 - \$37.08 = \$.17$
$\%MEB = \frac{\$ .53}{\$55.43} = 1.0$ percent	$\%MEB = \frac{\$ .17}{\$37.08} = 0.5$ percent

Note: All dollar amounts are expressed in 1978 dollars.

Secondary or indirect impacts of higher electricity prices may take place as a result of the rise in prices of goods and services produced in the commercial and industrial sectors. The extent of these impacts is basically a function of two factors -- a rise in the price of electricity to these users, and the relative share of electricity costs in the overall expenses of these firms. On the latter point, several studies (TBS 76, CEQ 72) concur that electricity costs represent only a few percentage points of the output of most industries. Regarding the size of the electricity rate increase, we have seen that for a 1 mill/kwh incremental cost of nuclear power there is only a slight impact on the prices paid by residential customers and since it was assumed that this incremental cost had the same relative impact on all electricity users, it follows that there will also be very little impact on commercial and industrial customers. Secondary impacts were estimated in one study (TBS 76) which concluded that they were insignificant while corresponding to a direct impact of 6.7 percent or a 2.1 mills/kwh (1975 dollars) increase in consumer charges in 1985. The rate increase in that study is much greater than the increase associated with a 1 mill/kwh incremental cost of nuclear power, as estimated above (see Table A-2), so that only minimal secondary impacts can be expected. In order to ascertain the secondary impacts of a hike in electricity prices in a reliable fashion, the use of a macroeconomic or input-output model would be required. However since the size of the price increase under analysis here is so small, it appears unwarranted to expend the necessary resources for such an exercise.

A.3 Regional Impact Analysis

A regional impact analysis was also performed to determine the degree of variation in the national estimates. As in the national case, the direct regional impacts on consumers from waste management are dependent upon the cost of producing electricity and the nuclear power share of electricity generation. The average residential electricity rate varies by a factor of more than 3 while the forecasted share of nuclear power in 1990 ranges from over 50 percent in the New England region to less than 2 percent for the Mountain States. The unit cost of waste management is assumed to be the same for every region due to the national scope of the radioactive waste problem. In reality, transportation costs would vary by region according to each utility's location to waste management facilities. However, since transportation costs are a relatively small portion of the program's total cost, about 15 percent (see Section 3.2, Table 3), a uniform cost for the entire waste management process was assumed.

In view of the size of the impacts on a nationwide basis, a single set of assumptions on the economic/energy parameters was used to develop the regional estimates. The assumptions used in the estimation were no growth in the real price of electricity for each region (from a 1978 base year), zero price elasticity of demand, and relative nuclear power shares which were based on a regional forecast from DOE which was presented in their 1977 report to Congress (DOE 77, Table 10-13).[1] Since the price

[1]Regional forecasts of nuclear power generation were not presented in the 1978 report to Congress (DOE 78); hence the forecasts for 1990 in the 1977 report were used. The difference in the two forecasts on a national level are a 26 percent nuclear share in 1990 according to the 1977 report, and a 22 percent share estimated in the 1978 report.

elasticity of demand is assumed to be zero, the relative impact on the residential electric bill is identical to the percentage increase in the residential electricity rate. Table A-3 summarizes the impact on the residential rate for each of the ten Federal Regions. Despite the regional differences in residential rates and the relative importance of nuclear power, the estimated impacts from a 1 mill/kwh cost of waste management ranged only from a high of 1.2 percent for Region I (Boston) and Region X (Seattle), to a low of 0.1 percent for Region VIII (Denver), compared to a national average of 0.8 percent. One observation worthy of note which serves to soften the diversity of regional impacts (expressed on a relative basis) from the waste management program, is that the areas with the highest shares of forecasted nuclear power generation -- the New England and Middle Atlantic States -- also represent the regions with the highest electricity charge to residential customers.[1] The higher the price of electricity, the smaller is the relative impact of the waste management program. As noted in the national analysis, because the direct impact on consumers is so small, secondary impacts were not calculated.

A.4 Summary

This appendix estimates the economic impacts associated with a 1 mill/kwh unit cost of the waste management program. Direct impacts to consumers on a national average basis are estimated to result in electricity rates in 1990 increasing by 0.6 percent ("realistic" case) to

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[1]It should not be concluded that the reason for these areas exhibiting high electricity prices is the relatively large nuclear share; the high prices are attributed to other factors.

TABLE A-3

Summary of Regional Impact (Direct)-1990-
of a 1 Mill/Kwh Waste Management Charge

Federal Region No. and Office Location	Percent of Electricity Generated by Nuclear Power 1976	1990	Residential Electricity Rate without Charge, 1990 (mills per kwh)	Increase in Residential Rate Due to Charge (mills per kwh)	Percent Increase in Residential Rate Due to Charge
I Boston	33.3	53.3	54.3	0.64	1.2
II New York City	14.6	38.4	63.3	0.46	0.7
III Philadelphia	11.9	25.9	46.4	0.31	0.7
IV Atlanta	9.0	27.4	36.3	0.33	0.9
V Chicago	14.2	28.6	42.5	0.34	0.8
VI Dallas	1.5	17.7	36.3	0.21	0.6
VII Kansas City	9.0	19.3	40.2	0.23	0.6
VIII Denver	0	1.5	35.7	0.02	0.1
IX San Francisco	2.9	25.9	42.6	0.31	0.7
X Seattle	0	18.5	18.5	0.22	1.2
Total U.S.	9.2	25.9	40.9	0.31	0.8

Note: Dollar amounts are expressed in 1978 dollars.

Sources: Nuclear shares are from the Department of Energy, Energy Information Administration, Annual Report to Congress, Volume II, 1977. The residential electricity rate was derived by calculating Institute, Statistical Yearbook of the Electric Utility Industry for 1976 and adjusting all rates to 1978 by the relative change in the consumer price index for electricity from 1976 to July,1978 (18.6 percent). Under the "maximum impact" assumptions, the real price of electricity remains the same from 1978 - 1990. The increase in the residential rate of electricity reflects the uniform pass-on of 1.2 mills per kwh, adjusted for nuclear power coverage. The 1.2 mills/kwh charge is derived by multiplying the ratio of the waste management charge to the national average total revenue requirement in 1990 (1.0 / 34.3), times the national average residential electricity rate in 1990 (40.9 mills/kwh).

1.0 percent ("maximum impact" case), in real terms. Regional variation should account for an upward deviation of about 50-60 percent of the national average impact. Secondary impacts on consumers have not been explicitly estimated, but are expected to be insignificant. The total annual cost of waste management in 1990, as reflected by the projected revenues to be collected from a waste management charge of 1 mill/kwh levied on electricity consumers in that year, is estimated to be about $825 million or 0.6 percent of total revenues.

As discussed at the beginning of this section, economic impacts from the waste management program or any other nuclear-related program, can be estimated from these normalized impacts by scaling them according to the relative proportion of the unit cost to the 1 mill/kwh assumption. This method will provide a reasonable estimate of the direct impact of higher electricity prices for any range of incremental costs. However, the larger the incremental cost under consideration, the greater the need to examine more closely the secondary impacts of the higher prices.

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APPENDIX B

ESTIMATION OF THE TOTAL COST OF THE REFERENCE COMMERCIAL WASTE MANAGEMENT PROGRAM

This appendix describes the procedure by which the total cost of the reference commercial waste management program was estimated. Costs are developed separately for existing and future spent fuel (the waste form assumed in the reference program). In both cases, the total cost was estimated by multiplying a unit cost by the appropriate number of total units.

The Department of Energy estimates that about 6000 MT of spent fuel have accumulated by the end of 1979 (DOE 80a). According to DOE's preliminary spent fuel charge report, the charge for "disposal only" (as opposed to interim storage and disposal) was estimated as ranging from $112 to $214 (1978 dollars) per kilogram of spent fuel (DOE 78b, Table 7). Adding $33/kg to each of these unit costs to represent the cost of transportation of the spent fuel to a repository site, increases the total unit cost to $145 to 247 per kilogram. Applying these unit costs to the existing inventory of spent fuel results in a total cost ranging from .87 to 1.482 billion dollars. This total cost covers transportation to a repository site, encapsulation, disposal, research and development, Government overhead, decommissioning (of the repository and the encapsulation facility) and surveillance.

For future waste, we estimated the cost pertaining to the spent fuel resulting from the cumulative generation of nuclear powered electricity projected for 1980 through 1995. The following forecast of nuclear kilowatt-hours was assumed:

Year	Nuclear Kwh (Billions)[1]
1979	255
1985	570
1990	825
1995	1115

The annual generation of nuclear-powered electricity was estimated for 1980 through 1995 by linear interpolation. The sum of the generation for each year of this time period totaled 12,244 billion kwh. As in the case of existing spent fuel, the unit cost of waste management was derived from estimates in DOE's preliminary spent fuel charge report (DOE 78b, Table 7). A range in the unit cost was assumed by using the lowest estimate of the charge for "disposal only" ($112/kg) and the highest estimate for "storage and disposal" ($319/kg). Adding $33/kg to each of these costs to represent the cost of transportation of spent fuel to Government facilities (either at an AFR storage site or a repository site) and converting to a direct fuel cycle cost (using a conversion factor of $250/kg = 1 mill/kwh) results in a unit cost of waste management ranging from .6 to 1.4 mills per kwh. Applying these unit costs to the cumulative nuclear power generation projected for 1980 through 1995 results in a total cost of 6.746 to 15.742 billion dollars. As explained in Chapter 3

[1]The estimate for 1979 is from DOE 80b and the projections are from DOE 78a, Table 12.3.

of this document, this cost is a sum of annual revenues to be collected from electric utility customers at time of generation to pay for the cost of waste management activities which will take place several years after electricity generation. This cost includes AFR storage for a portion of the spent fuel, transportation to both an AFR storage site and repository site, encapsulation, disposal, research and development, Government overhead, decommissioning (of the repository, encapsulation, and AFR storage facilities) and surveillance. This cost does not include the cost for storage of spent fuel at reactor sites.

The sum of the waste management costs for both existing spent fuel and the fuel to be used in nuclear-powered electricity generation from 1980 through 1995 ranges from 7.6 to 17.2 billion (1978) dollars. The cost for existing spent fuel represents about 10 percent of the combined total cost.

REFERENCES for APPENDIX B

(DOE 78a) U.S. Department of Energy, Energy Information Administration, Annual Report to Congress 1978, Volume III.

(DOE 78b) U.S. Department of Energy, Preliminary Estimates of the Charge for Spent-Fuel Storage and Disposal Services, July 1978, DOE/ET-0055.

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(DOE 80b) U.S. Department of Energy, Energy Information Administration, Monthly Energy Review, August 1980.

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16. ABSTRACT

This report estimates the potential economic impacts of EPA's proposed standards and guidance for the management and disposal of spent fuel, high-level, and transuranic radioactive wastes. The economic analysis assumes that the standards and guidance will have an incremental effect on the reference waste management programs that are assumed to take place in the future. Both commercial and defense waste management programs are covered. For the commercial sector, the impact of the standards on electricity rates is investigated.

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